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Useful knowledge, 'industrial enlightenment', and the place of India*

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Abstract

Research is now turning to the missing place of technology and 'useful knowledge' in the debate on the 'great divergence' between East and West. Parallel research in the history of science has sought the global dimensions of European knowledge. Joel Mokyr's recent The Enlightened Economy *(2009) argued the place of an exceptional 'industrial enlightenment' in Europe in explaining industrialization there, but neglected the wide geographic framework of European investigation of the arts and manufactures. This article presents two case studies of European industrial travellers who accessed and described Indian crafts and industries at the time of Britain's industrial revolution and Europe's Enlightenment discourse on crafts and manufactures. The efforts of Anton Hove and Benjamin Heyne to 'codify' the 'tacit' knowledge of a part of the world distant from Europe were hindered by the English East India Company and the British state. Their accounts, only published much later, provide insight into European perceptions of India's 'useful knowledge'.*

Keywords East India Company, Enlightenment, India, Industrial Revolution, technology

Introduction

During the past ten years there has been a new foregrounding of the role of India and China in understanding the early phases of European industrialization. China and India were the 'first industrial regions' providing manufactured export goods on a mass scale to markets throughout the world, as they are now doing once again. Europeans of the seventeenth and eighteenth centuries sought out Asia's 'exotics', followed by its export-ware products. They also sought to understand manufacturing systems adept at providing the goods that people at a distance wanted to buy. Products and quality were as significant to this trade as were productivity growth. Theirs was the industry that ultimately stimulated

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the technological transformation in Europe. European manufacturers and inventors throughout the latter half of the eighteenth century tested their patents, projects, and products against the great achievements of translucent Chinese porcelain and Indian textiles in madder red and indigo dyes, in glorious prints, or in the textures of the finest muslins. This is the story that should precede our explanation of European Enlightenment and industrialization.

How we study this Asian impact on ways of thinking about technology, as well as industrial practices in Europe, leads us into the new historiographies of global history, and the big question that has dominated much of the economic history written in this framework, namely 'the great divergence'. While these approaches have challenged us to compare West and East, they have been less successful at connecting ideas, products, and technologies between these two parts of the world. A major incentive behind Europe's new manufacturing technologies (especially in textiles, ceramics, and other consumer goods) was the drive to produce quality products that would compete with imported Asian goods. Attempting to understand this must lead us to consider questions of products, quality, and commodities; these are all key aspects of material culture. Connected with this was the problem of producing such goods, of that combination of 'tacit' and 'codified' knowledge that we now call 'useful knowledge'.

Recent articles in this journal, notably those by Tirthankar Roy and Giorgio Riello, have introduced the issue of 'useful knowledge'. Prasannan Parthasarathi's recent book addresses the missing place of technology and useful knowledge in the divergence debate. Changing European perceptions of the quality of Chinese porcelain and the skill of its producers are also among themes of an article by Gerritsen and McDowall.[1] Parallel research in the history of science has sought the global dimensions of European knowledge, and the connections of academic learning in Europe to wider world commerce. Harold Cook has recounted many cases of medical, botanical, and chemical knowledge transported and 'translated' to European environments from India and South East Asia, Taiwan, and Japan via Dutch East India Company doctors, merchants, and local intermediaries. Schaffer, Roberts, Raj, and Delbourgo have taken this further to emphasize the interaction between the mobile figures of trade, the cultures that they encountered, and knowledge acquisition. They argue that networks of travel, enquiry, exchange, and espionage contributed to the distribution and adoption of new practices and technologies. There is a new focus on agents, local experts, or 'go-betweens'. Klein and Spary have delved further into the industrial and commercial base of the early modern scientific investigation of materials and resources; they link artisanal and learned practices, manufacture and the 'sciences'.[2]

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1 Tirthankar Roy, 'Knowledge and divergence in early modern India', *Journal of Global History*, 3, 3, 2008, pp. 379–385; Giorgio Riello, 'Asian knowledge and the development of calico printing in Europe in the seventeenth and eighteenth centuries', *Journal of Global History*, 5, 1, 2010, pp. 1–28; Prasannan Parthasarathi, *Why Europe grew rich and Asia did not*, Cambridge: Cambridge University Press, 2011; Anne Gerritsen and Stephen McDowall, 'Material culture and the other: European encounters with Chinese porcelain, c. 1650–1800', *Journal of World History*, 23, 1, 2012, pp. 87–113.

2 Harold J. Cook, *Matters of exchange: commerce, medicine, and science in the Dutch golden age*, New Haven, CT: Yale University Press, 2007; Simon Schaffer, Lissa Roberts, Kapil Raj, and James Delbourgo, eds., *The brokered world: go-betweens and global intelligence, 1770–1820*, Sagamore Beach, MA: Watson Publishing, 2009; Ursula Klein and E.C. Spary, *Materials and expertise in early modern Europe*, Chicago: University of Chicago Press, 2006.

'Useful knowledge', is now being investigated by both economic historians and historians of science to challenge historians to connect industry, work, and trade to scientific and inventive activity. A global framework for this research invites us to reach beyond the broad core of research from the 1980s and 1990s on empire and botany to enquire into the wider extension of Europe's Enlightenment investigation of arts and manufactures to Asian entrepots. Joel Mokyr has argued the centrality of a new culture of scientific investigation and technological improvement both to Europe's Enlightenment and to its industrialization,[3] and he makes a case for an 'industrial enlightenment' that was part of the wider public culture of enlightenment.[4] Some have disputed the 'exceptionalism' of his account; for the most part these critiques have sought parallel scientific and technological experiences in China or India.[5] They have not enquired into the wide geographic framework of that European investigation of arts and manufactures. This investigation was stimulated by the Asian manufactured goods flowing into Europe by the eighteenth century, and it extended into discovering the secret arts and manufacturing processes of Asia. Europe's 'industrial enlightenment' ranged well beyond Europe to investigate Asia's resources, industries, and manufactures.

This article tackles the question of how Europeans accessed Asian crafts, and how they described and analysed Asia's industries at the time of Britain's Industrial Revolution and Europe's Enlightenment discourse on the crafts and manufactures. It does so through two case studies of European industrial travellers and investigators seeking to understand the industrial products and manufacturing processes of eighteenth-century India. These travellers, Anton Hove and Benjamin Heyne, one a Pole and the other a German, were part of a culture of 'savants' and investigative travel that we associate with the European Enlightenment. But their travel in India and the dissemination of their accounts afterwards were deeply entangled with the British state and the English East India Company (EIC). They undertook wide travels – in Hove's case in western India and Gujarat; in Heyne's in south India – but the accounts that they wrote afterwards languished for years in the India Office Records. Because of this, historians can claim no impact of these accounts on European knowledge; even their contribution to EIC information gathering was probably tangential.

Historians have largely ignored them. A careful reading of the accounts, however, reveals an intellectual framework of investigative industrial travel of a form common in Europe at the time but less common in India. I will relate their expeditions to other enlightened travel and information gathering in India, and suggest that such accounts form a part of what Mokyr has termed the 'industrial enlightenment'. The politics that underpinned their very late publication demonstrate the uncertainties and obstructions in the circulation of knowledge. Interrogated thus, such texts contribute to a wider body of evidence to show that Mokyr's 'enlightened economy', conceived by him as a European affair, also extended to efforts to engage with the arts and manufactures of Asia.

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3 Joel Mokyr, *The enlightened economy: an economic history of Britain 1700–1850*, New Haven, CT: Yale University Press, 2009.

4 *Ibid*., pp. 79–98.

5 See, for example, Parthasarathi, *Why Europe*, pp. 185–222; Kapil Raj, *Relocating modern science: circulation and the construction of scientific knowledge in South Asia and Europe*, Basingstoke: Palgrave, 2007; Ian Inkster, 'Potentially global: "useful and reliable knowledge" and material progress in Europe, 1474–1914', *International History Review*, 27, 2006, pp. 237–86.

Asian material culture, useful knowledge, and political economy

Imports from Asia were on one level an exchange of material cultures. Such imports, however, were also vital to the learning and knowledge formation underpinning Europe's remarkable response to Asian manufacturing leadership in the seventeenth and eighteenth centuries.[6] That response was in the first place about accessing a whole new level of diverse high-quality consumer goods. Cultivation of an export-ware sector by the East India Companies entailed industrial development in Asia and marketing there and beyond to Europe, which focused on variety, quality, and quantity. Second, there was a process of imitative invention in Europe to create a consumer goods sector on a whole new scale. This was based in product innovation, new technologies, and organization. The widespread import of Asian goods into Europe from the seventeenth century onwards came with dense information networks which fostered markets but which also spurred those involved to envisage changing materials, adapting designs, and introducing new techniques that would break through traditional processes.

Eighteenth-century political economists and manufacturers understood this. They saw that the impact of Asia was one of both material culture and useful knowledge. What Europeans appreciated was the scale and diversity of those Asian imports. The Asian technologies were based on imitative principles: modularity, standardization, and mechanical replication, and yet they produced high-quality goods and diverse outputs.[7] In eighteenth-century terms, exotic ornament was being turned into 'modern luxuries'. Debates on this increasingly relied not just on products imported from Asia but also on 'useful knowledge' gathered in the course of the EIC trade.

The focus in current studies on Asian imports leads to a new interrogation of connections, in material culture, in the making and trading of commodities, and in the knowledge of production. This in turns leads into issues raised by Mokyr's books over the past decade, which have given agency to culture in explaining industrial development and economic growth. He argues the case for an 'industrial enlightenment', which preceded and accompanied the Industrial Revolution. That industrial enlightenment was based in the belief that material progress and economic growth could be achieved through increasing human knowledge of natural phenomena. 'Useful knowledge', in turn, was knowledge of natural phenomena that might be manipulated by human endeavour: it encompassed practical and informal knowledge as well as theory and codified formal knowledge; it included the work of those who collected observations and who compiled dictionaries and encyclopaedias of arts and manufactures with their descriptions of industrial skills and crafts.[8] It also included 'tacit' knowledge transmitted through artisan skill.[9]

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6 Maxine Berg, 'In pursuit of luxury: global history and British consumer goods in the eighteenth century', *Past and Present*, 182, 2004, pp. 85–142.

7 See Lothar Ledderose, *Ten thousand things: module and mass production in Chinese art*, Princeton, NJ: Princeton University Press, 2001; Dagmar Schäfer, *The crafting of the 10,000 things: knowledge and technology in seventeenth-century China*, Chicago, IL: University of Chicago Press, 2011.

8 Joel Mokyr, *The gifts of Athena: historical origins of the knowledge economy*, Princeton, NJ: Princeton University Press, 2002; Mokyr, *Enlightened economy*; Joel Mokyr, 'The intellectual origins of modern economic growth', *Journal of Economic History*, 65, 2, 2005, pp. 285–351.

9 Mokyr, *Gifts of Athena*; Mokyr, *Enlightened economy*, pp. 29, 321; Mokyr, 'Intellectual origins', pp. 296, 318–21.

Mokyr has made a case that the West developed a very specific 'useful knowledge'. Part of that discussion has centred on differences between the West and the East: Mokyr takes a firm line that the real divergence between the West and the rest of the world did not arise from differences in resource endowments but from a 'knowledge revolution' that took place in the West and not elsewhere. Mokyr believes, as have his critics, Epstein and Allen, that this knowledge revolution was Europe's 'miracle' compared to the rest of the world:[10] 'To create a world in which "useful" knowledge was indeed *used* with an aggressiveness and a single-mindedness that no other society had experienced before was the unique Western way that created the modern material world.'[11] He distinguishes Europe's, and especially Britain's, skilled artisans from those in other parts of the world, arguing that Britain had a special endowment of competent skilled workmen who could make use of new technologies; they could thus advance 'microinventions'. They were strategically placed at coincident times in clock- and instrument-making, the shipbuilding and shipping industries, and in mining and its associated technologies.

Mokyr has further provocatively declared: 'Many societies we associate with technological stasis were full of highly skilled artisans, not least of all Southern and Eastern Asia'. This contrasts with 'a society where the world of artisans is constantly shocked with infusions of new knowledge from outsiders'.[12] Such a statement assumes that artisan groups in South and East Asia were static and sedentary. Historians of India have reminded this staunch Europeanist of extensive evidence from South India of high labour mobility among craftsmen, and production centres such as the shipyards of Gujarat and those of the Coromandel coast that integrated different groups of workers, who also adapted some of their techniques to those practiced by English artisans.[13]

Europe's technologies did not, furthermore, develop within a totally separate European sphere. The 'useful knowledge' developed within an 'industrial enlightenment' included European engagement with the technologies of other parts of the world. In the case of manufacturing and the processing of resources, Asia was of crucial interest. It is important, therefore, to research the travel writings of those Europeans who investigated manufactories and other industrial settings beyond their home environs, and described skills and processes.

Aspects of this subject have been approached by historians of science, but they have until recently confined their interests mainly to the transmission of knowledge of natural history,

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10 Maxine Berg, 'The genesis of "useful knowledge"', in Maxine Berg, ed., 'Reflections on Joel Mokyr's *The gifts of Athena*', *History of Science*, special issue, 45, 2, 2007, pp. 123–35; S. R. Epstein, 'Craft guilds, apprenticeship, and technological change in preindustrial Europe', *Journal of Economic History*, 53, 3, 1998, pp. 684–713; S. R. Epstein, 'Transferring technical knowledge and innovating in Europe, c. 1200–1800', working paper on 'The nature of evidence: how well do facts travel?' 01/05, May 2005, http://www2.lse.ac.uk/economicHistory/pdf/FACTSPDF/FACTS1-Epstein.pdf (consulted 3 December 2012); Robert Allen, *The British industrial revolution in global perspective*, Cambridge: Cambridge University Press, 2009.

11 Mokyr, *Gifts of Athena*, p. 297. See also Joel Mokyr, 'Knowledge, enlightenment, and the industrial revolution: reflections on *The gifts of Athena*', in Berg, 'Reflections', pp. 186–96.

12 Mokyr, *Enlightened economy*, p. 61.

13 David Washbrook, 'India in the early modern world economy: modes of production, reproduction, and exchange', *Journal of Global History*, 2, 2007, pp. 87–112; Parthasarathi, *Why Europe*, pp. 203–13; Prasannan Parthasarathi, 'Agriculture, labour, and the standard of living in eighteenth-century India', in Robert C. Allen, Tommy Bengstsson, and Martin Dribe, eds., *Living standards in the past: new perspectives on well-being in Asia and Europe*, Oxford: Oxford University Press, 2005, pp. 99–109.

medicine, and astronomy. They have demonstrated the great interest at the time in the crops and plants of the wider world, and they have compiled large histories of the botanical collectors of the eighteenth century.[14] Developing concepts of 'cosmopolitan science', they have focused on decentring European science, and setting it in a world history framework. They address networks of information structuring the worldwide exchange of knowledge, and discuss interaction and exchange, networks and circuits, and local knowledge and contact zones.[15] They argue that European science was only one way of conceptualizing the natural world, one that built, moreover, on the local knowledge acquired by European naturalists, 'journeying on survey with expert pundits … across newly mastered lands'.[16] 'Borderlands' and 'contact zones' were a kind of 'middle ground', spaces where asymmetrical relations 'might be even temporarily suspended or modified in favour of more local economies of dependence and interest'.[17] Travelling naturalists were also 'unpredictable'. Historians have shown them to be willing to engage in varieties of sensory experience and moving through 'exotic' cultural zones, yet also presenting themselves at times in direct encounter with nature, discounting the local mediation upon which they depended.[18]

The closest connection of botanical and natural history collecting to the economy of 'useful knowledge' can be found in the detailed attention given by travellers to the materials and techniques of textile dyeing. Textile historians frequently recount the reports on dyeing and printing by Father Coeurdoux and William Roxburgh. These well-known texts, as well as others by Georges Roques (1678–80) and Antoine Georges Nicolas de Beaulieu (1692–1764), were closely considered by P. R. Schwarz and John Irwin in the 1950s. Giorgio Riello has more recently reconsidered the limited impact that such accounts actually had on European textile printing. He draws attention to European interest in the production processes of dyeing and printing, and the real effort of contemporary writers to provide clear descriptions of economic value to savants and manufacturers back in Europe.

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14 Ray Desmond, *The European discovery of the Indian flora*, Oxford: Oxford University Press, 1992; John Gascoigne, *Joseph Banks and the English Enlightenment: useful knowledge and polite culture*, Cambridge: Cambridge University Press, 1994; Richard Drayton, *Nature's government: science, imperial Britain, and the 'improvement of the world'*, New Haven, CT: Yale University Press, 2000; Londa Schiebinger and Claudia Swan, *Colonial botany: science, commerce, and politics in the early modern world*, Philadelphia, PA: University of Pennsylvania Press, 2005; David Miller and Peter Hans Reill, eds., *Visions of empire: voyages, botany, and representations of nature*, Cambridge: Cambridge University Press, 1996; Cook, *Matters of exchange*.

15 Antonella Romano and Stéphane Van Damme, 'Science and world cities: thinking urban knowledge and science at large (16th–18th century), *Itinerario*, 33, 1, 2009, p. 80.

16 Simon Schaffer, 'The Asiatic enlightenments of British astronomy', in Schaffer et al., *Brokered world*, p. 65.

17 Lissa Roberts, 'Situating science in global history: local exchanges and networks of circulation', *Itinerario*, 33, 1, 2009, p. 21. For further accounts see James Delbourgo and Nicholas Dew, eds., *Science and empire in the Atlantic world*, New York: Routledge, 2008; Elizabeth Green Musselman, 'Indigenous knowledge and contact zones', *Itinerario*, 33, 1, 2009, pp. 31–44; Kapil Raj, 'The historical anatomy of a contact zone: Calcutta in the eighteenth century', *Indian Economic and Social History Review*, 48, 1, 2011, pp. 55–82. See also Kapil Raj, *Relocating modern science*, tellingly reviewed by Tirthankar Roy, *Journal of Global History*, 3, 1, 2008, pp. 129–31; Philip B. Wagoner, 'Precolonial intellectuals and the production of colonial knowledge', *Comparative Study of Society and History*, 45, 2003, pp. 783–814; Schaffer et al., *Brokered world*.

18 James Delbourgo, 'Fugitive colours: shamans' knowledge, chemical empire, and Atlantic revolutions', in Schaffer et al., *Brokered world*, p. 285; Andreas Weber, 'Encountering the Netherlands Indies: Caspar G.C. Reinwardt's field trip to the East 1816–1822', *Itinerario*, 33, 1, 2009, pp. 45–60.

The descriptions were, however, read by eighteenth-century chemical writers, and manufacturers such as Oberkampf did attempt to apply the methods.[19]

Approaches to texts on industrial practices such as these have hitherto fallen into a rather functionalist methodology. Those analysing them focus only on whether they were correct or whether they were actually used by Europeans. There has been little attempt to place such accounts of industry within a wider intellectual and cultural endeavour of Enlightenment 'useful knowledge', and within the 'knowledge gathering' of statecraft; the trade in commodities with the East became closely bound up with a reflection on the knowledge of manufactures in other parts of the world. Nevertheless, we can now look to motivations for gathering this knowledge as an aspect of statecraft, of colonialism, and of empire.

Bayly provides a detailed account of information gathering and communication in Mughal India and in the courts. EIC and colonial information gathering relied on these pre-colonial institutions to gather knowledge at many different levels. From early in the seventeenth century, the English and Dutch East India Companies and private traders collected detailed commercial information on Indian textiles, including forms and processes of production, drawing much information from agents, *banian*s (Hindu traders), and *dubash*es (interpreters or commissionaires), their goals being to control sources of supply and profitable trade. Bayly shows how Company servants drew commercial and some production information from the petitions of Indian textile producers and from the Company's Indian agents in the factories, and later from their permanent commercial agents and from private traders, often Armenians. But they still had little contextual knowledge of social and economic conditions impinging on technologies and levels of production in the hinterland.[20]

Of course the more systematic gathering of information on technologies and resources in the eighteenth century might simply be encompassed in the imperial endeavours of accumulating botanical knowledge.[21] There is the case of the collectors sent out by Joseph Banks, who himself aspired to 'order' the chaotic natural world of empire. By this interpretation, European collectors 'helped to incorporate new lands and colonies into a British scientific and industrial hegemony'.[22] But the complexities of the individuals involved, how they set about their empirical investigations, and how they described, 'codified', and conveyed what they saw must also take us into wider aspects of the Enlightenment.

A knowledge of manufactures and industrial resources can be recovered first in contemporary economic writing, addressed to the characteristics and qualities of products, innovation based in artisan skill, and learning from China and India. The intellectual framework for this was established by the analytical political economists of the early and mid eighteenth century, who saw that import substitution, multiplied by imitation, could yield a radical reconfiguration of the commodity, and with this new consumer markets.[23]

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19 Riello, 'Asian knowledge'.

20 C. A. Bayly, *Empire and information: intelligence gathering and social communication in India 1780–1870*, Cambridge: Cambridge University Press, 1996, pp. 21–5, 30–6, 44–55.

21 David Mackay, 'Agents of empire: the Banksian collectors and evaluation of new lands', in Miller and Reill, *Visions of empire*, pp. 38–56.

22 *Ibid.*, p. 54.

23 Maxine Berg, 'Pursuit of luxury', pp. 130–1.

At a less abstract level, the political economy of products took the form of an extensive print culture of dictionaries and encyclopaedias, itself closely linked to a network of Societies of Improvement. Postlethwayt set out the purpose of the 1774 new edition of his *Universal dictionary* as being to look at the dependence of the prosperity and trade of the British nation on the mechanical and manufactured arts. Government and the legislature needed to support these so that 'their industrious ingenuity may not be surpassed by any rival nation, especially France'.[24] Postlethwayt's focus on 'useful knowledge' was a prescient appreciation of the tacit skills of the artisans over the speculations of science:

> The due cultivation, therefore, of practical manual arts in a nation, has a greater tendency to polish and humanize mankind, than the mere speculative science, however, refined and sublime it may be: and these practical arts are not only the most naturally adapted to the bulk of the people, but, by giving real existence to their ideas, by their practical inventions, improve their minds more sensibly and feelingly than any ideal contemplation could do, which may have no other being but in the mind of the speculator.[25]

Postlethwayt's *Dictionary* would also address

> the commerce of the Chinese, and the East Indies, in general; by what means they are carried on. – Of the excessive cheapness of their arts, manufactures, and produce; whereby all European nations are attracted to trade with them, and resort to them for their productions and manufacture. With pertinent observations to carry on their commerce both in a private and public way, and best to the advantage of Europe.[26]

European travellers also collected the knowledge of manufactures from around the world. In the sixteenth and seventeenth centuries, they first recounted mysterious and exotic methods of producing silk, lacquer, and porcelain in China, and subsequently provided greater detail and more critical comment. Gerritsen and McDowall find a new disillusion with Chinese craft techniques among European travellers to East Asia by the early eighteenth century. As Europe's familiarity with Chinese imports grew, along with circulating accounts of craft processes, so her admiration for China's technologies declined.[27] These accounts were still relatively rare, and few provided great empirical or analytical depth. Even in the case of botanical collecting, long-standing and continued European collections of Chinese plants were achieved in the face of constant restrictions and of difficulties in moving beyond Canton. Great commercial interest in Chinese decorative plants complemented efforts to collect tea plants, Chinese hemp, and natural lacquers.[28]

More ambivalent perspectives, but also serious empirical investigations of crafts, manufactures, and resources, were conveyed by some Europeans in India, where 'useful knowledge' was perceived to be much more accessible than in the case of China.[29] Bayly has

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24 Malachy Postlethwayt, *The universal dictionary of trade and commerce*, 4th edn, London: W. Strahan, 1744, vol. 1, p. v.

25 *Ibid*., vol. 1, 'Artisans'.

26 *Ibid*., vol. 2, 'Porcelain'.

27 Gerritsen and McDowall, 'Material culture', pp. 10–15, 20–2.

28 Mackay, 'Agents of empire', pp. 45, 51.

29 *Ibid*., p. 45.

recounted how the EIC developed early expertise on Indian textile production, and acquired effective commercial information. In the early eighteenth century, European understandings were lost with the decline of Jesuit and Dutch accounts. But greater power over the land-revenue management of Bengal made for easier European travel and mapping: 'Power over revenue gave access to a much wider range of information within the Indian polity'.[30] Along with the mapping of territories, there was a gathering of information on India's resources, agronomy, and manufacturing.[31]

During the key period of the 1780s and 1790s, nothing was certain in terms of global manufacturing. India's cotton industry was still producing the greatest part of the world's textiles, but Britain's industry was mechanizing and growing rapidly. Britain's iron industry, transformed by coal-fired smelting, met all challengers apart from that of the Swedes, and her fine metal manufactures were the wonder of the rest of Europe. From the mid-eighteenth century, manufacturers, industrial spies, and technological investigators travelled, collected, and translated processes they found across Europe. The diary of the Swedish R. R. Angerstein's travels in the British Isles in 1753–55, with its detailed accounts and drawings, is but one example.[32] Gaining industrial ascendancy in Europe also involved collecting information on resources and processes across the wider world, especially those to be found in India. Industrial spies and investigators, but also those with a wider enlightened interest in 'useful knowledge', found their way to India, which they could access through the East India Companies and through Catholic and Protestant missions.

Europeans and useful knowledge in India

Two cases convey the priorities of and depth of research into Indian resources and manufacture: the journeys of Anton Hove in western India and those of Benjamin Heyne in south-eastern India. They also demonstrate the ambivalence over gathering 'useful knowledge', for they were two cases of failure. The projects of collecting information were ambitious but the goals were unclear, and the agencies involved, especially the British state and the EIC, were at odds. Neither investigator was British, and both had conflicting or difficult relations with the EIC. Ultimately, their sophisticated and detailed industrial surveys were only published much later, in the nineteenth century: 1814 in the case of Heyne and 1855 for Hove. Preliminary drafts, reports, and letters languished in the records of the EIC and in the correspondence of Joseph Banks and William Roxburgh. It is likely that few in Europe learned from the information gathered, except through the unattributed details and evidence in the writings of Banks and Roxburgh, those two leading figures in late Enlightenment natural history.

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30 Bayly, *Empire*, p. 49.

31 Matthew Edney, *Mapping an empire: the geographical construction of British India, 1765–1843*, Chicago, IL: University of Chicago Press, 1997, pp. 9–47.

32 See R. R. Angerstein, *Illustrated travel diary, 1753–1755: industry in England and Wales from a Swedish perspective*, trans. Torsten and Peter Berg, London: Science Museum, 2001. See also J. R. Harris, *Industrial espionage and technology transfer: Britain and France in the eighteenth century*, Aldershot: Ashgate, 1998; Liliane Hilaire-Pérez, *L'invention technique au siècle des lumières*, Paris: Albin Michel, 2000; Chris Evans and Göran Rydén, *Baltic iron in the Atlantic World in the eighteenth century*, Leiden: Brill, 2007; Christine MacLeod, 'The European origins of British technological predominance', in Leandro Prados de la Escosura, ed., *Exceptionalism and industrialism: Britain and its European rivals, 1688–1815*, Cambridge: Cambridge University Press, 2004, pp. 111–26; Giorgio Riello and P. K. O'Brien, 'The future is another country: offshore views of the British industrial revolution', *Journal of Historical Sociology*, 22, 2009, pp. 1–29.

Nevertheless, this material reveals a world of savants attempting to identify and to map mineral resources, and to codify manufacturing processes. It demonstrates an 'enlightened' framework of enquiry, a gathering of 'useful knowledge', and an informed curiosity in wider-world resources, technologies, and skills. Hove's and Heyne's accounts of global useful knowledge reveal challenging journeys of discovery and close reliance on local knowledge; they show the difficulties of penetrating secret 'tacit' knowledge. Nevertheless, they left detailed descriptions of labour and craft in a number of industries, and speculated on the application of scientific theory. They complicate that picture of Western hubris conveyed by Mokyr's 'enlightened economy', in that they reveal the wider reach of Enlightenment enquiry into the industrial practices of India while at the same time showing early ideas on mapping and using India's resources, and on developing her industries to the benefit of the EIC.

Dr Anton Hove, a Polish doctor, savant, and naturalist, was one of Joseph Banks's collectors and agents. Sent by Banks under the subterfuge of collecting plants for Kew, his real mission was to gather the best cotton plants of Gujarat and to discover the methods and tools of fine spinning and cotton weaving. The issues of procurement and quality of raw cotton and fabrics, which lay behind these intensely detailed enquiries into local conditions of the textile manufacture, were vital in attempts to gather 'useful knowledge' in an emerging cotton textile industry located 4,500 miles from Surat and Bombay.

British manufacturers, who faced the fierce competition of hand-painted Indian textiles and hand-spun and woven muslins, realized that the advantage of these Indian fabrics lay in quality and price. In a highly charged atmosphere of competition and high demand, workshops and factories in Lancashire and Mulhouse produced high-quality goods, rapid design change, and prices afforded by the middle and then the labouring classes. Samuel Oldknow started a muslin manufacture in Stockport in 1782; he used what was then called the muslin wheel, Crompton's mule, invented in 1779. His markets were in London's fashion trade, and his products competed directly with those of India, facing a 'severe burst of competition' whenever EIC vessels unloaded cargoes of textiles.[33]

A committee convened in 1812 to consider Crompton's petition for some compensation for the invention he never patented claimed that 'in the invention of the mule may be found one of the chief causes of the transference of the seat of an industry to the Western from the Eastern world, where it had been situated from time immemorial'.[34] This very close entanglement of Indian textile manufacture and the technological development of the emerging British industry are subjects explored by Prasannan Parthasarathi. He sets out the significance attached by British manufacturers and inventors to attaining a cotton yarn quality to match that achieved by Indian spinners. But these issues both of quality and of India's challenge in world markets were gradually written out of the history of the British cotton industry and industrialization from the nineteenth century onwards.[35]

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33 George Unwin, *Samuel Oldknow and the Arkwrights*, Manchester: Manchester University Press, 1924, p. 7. See also Maxine Berg, 'Quality, cotton and the global luxury trade', in Giorgio Riello and Tirthankar Roy, eds., *How India clothed the world: the world of South Asian textiles, 1500–1850*, Leiden: Brill, 2009, pp. 391–414.

34 Cited in George Daniels, *The early English cotton industry*, Manchester: Manchester University Press, 1920, p. 129.

35 Parthasarathi, *Why Europe*, pp. 98–110.

Anton Hove's close analysis of not only cotton plants and cultivation but also spinning and weaving processes and technologies during the 1780s takes us to the heart of both the product and the market development of material culture, and the collection of useful knowledge from Asia. The motivation behind Hove's reports on Surat and Gujarat in 1787 lie in the special circumstances of both the region and the British cotton industry, the textile industry providing the trade from Surat being of rising interest to the EIC in the 1780s and 1790s.[36]

Surat emerged as a major centre for the production of textiles during the 1780s; by the early 1790s the city boasted 15,777 looms worked by specific weaving groups. There was a great demand for the cloth produced there, but along with this a concern over access to good-quality products. The Company reported 'a very small proportion of the weavers in Surat could manufacture the kind of goods that the company specified … "only the young and strong could reach the excellence of the Company's fabric whereas old men, women and children can make such goods as foreigners and native merchants will purchase"'.[37] At the time, however, the authority of the EIC in the area was more limited than in Bengal. The Company faced the threat of both the Marathas and also a range of European private traders, especially the Portuguese, and the strength of Indian merchants.

Surat in the mid eighteenth century boasted a large merchant population, with ships sailing to many Indian Ocean ports, while Indian merchants and portfolio traders benefited from Arab investment in shipping from the Arabian Peninsula. Merchants of Surat traded textiles from Kachchh to the Malabar coast; other merchants traded cotton to Bengal and China.[38] The background of the Maratha threats on the coast, and hostility from Mysore, enhanced the strength of Indian merchants in Bombay. There was a significant migration of Bania merchants into Bombay from Kachchh, Gujarat, and Sindh in the 1770s and 1780s; they formed associations and cartels, and provided marine insurance and *respondentia* business.[39] Muslim and Parsi merchants shipped their own cargoes, let out tonnage to others, and provided brokerage and credit.[40] The EIC thus operated in a complex system of Muslim, Hindu, and Parsi merchants and ship-owners, as well as European competitors,

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36 Lakshmi Subramanian, 'The political economy of textiles in western India: weavers, merchants and the transition to a colonial economy', in Riello and Roy, *How India clothed*, pp. 253–80; Ghulam Nadri, *Eighteenth-century Gujarat: the dynamics of its political economy, 1750–1800*, Leiden: Brill, 2009.

37 Commercial Department Diary of the Bombay Government No. 9 of 1794, 'Results of the Enquiry Committee instituted by the Surat Council to examine the problems of investment', pp. 134–5, quoted in Subramanian, 'Political economy', p. 269. Also see British Library, India Office Records (henceforth BL, IOR), FRS 73, Proceedings, Surat 11 Sept. 1795; Factory Records Surat Accession No. G/36], pp. 453–4.

38 Ghulam A. Nadri, 'Sailing in hazardous waters: maritime merchants of Gujarat in the second half of the eighteenth century', in Om Prakash, ed., *History of science, philosophy and culture in Indian civilization*, vol. 3 (7), Delhi: Pearson, 2012, pp. 255–84, esp. pp. 257–8, 260, 265–6. See also H. V. Bowen, 'Britain in the Indian ocean region and beyond: contours, connections, and the creation of a global maritime empire', in H. V. Bowen, Elizabeth Mancke, and John G. Reid, eds., *Britain's oceanic empire: Atlantic and Indian ocean worlds, 1550–1850*, Cambridge: Cambridge University Press, 2012, pp. 45–66, esp. pp. 51–7.

39 Lakshmi Subramanian, 'Reaping the risks of transition: merchants and trade in Western India, 1750–1818', in Prakash, *History of science*, pp. 285–307, esp. p. 290. See also Lakshmi Subramanian, 'Seths and sahibs: negotiated relationships between indigenous capital and the East India Company', in Bowen, Mancke, and Reid, *Britain's oceanic empire*, pp. 311–39.

40 Nadri, 'Sailing', p. 259.

especially Portuguese private traders. Indeed, Company ships often sailed in convoy with a whole range of smaller ships to Kachchh and Sindh in the north, to Bombay and south to the Malabar coast, and even around to Bengal.

Beyond the EIC's concerns over the quality and measurement of manufactured cotton fabric from the region, there were other problems in Britain regarding raw cotton imports. British cotton manufacturers faced constraints on their access to adequate supplies of raw cotton at a time of disruptions in trade with the Americas and the Levant in the aftermath of the American Revolution, and during conflicts with the French. A new interest in raw cotton cultivation in the colonies and prospects for transferring fine grades of cotton seeds and plants to the Caribbean, prompted Hove's expedition.

Banks's letter hiring Hove came with confidential documents:

> the real object of your mission is to procure for the West Indies seeds of the finer sorts of cotton with which the Ahmood Country [in the Broach District, Gujarat State] where you are ordered to reside abounds, to make yourself master of the manner in which it is cultivated, & transmit from time to time your observations upon the soil & mode of cultivation; you are continually to keep that in view as your main object, & consider the collections for His Majesty's garden as secondary to it.[41]

He was assured by Banks that his 'progress into the country will be safe & Easy. The Governor is also authorized to Furnish you with such money … not exceeding the sum of £300'. Hove's first station was to be an area lately under the occupation of the Company, and he would 'find it Easy to live there & learn among the inhabitants who have been used to Europeans how to conduct yourself'.[42]

Hove arrived in Bombay on 29 July 1787, but he was far from finding an easy passage out to India, or his travels there supported by the Governor and Council of Bombay. On the contrary, 'everywhere he found crime, corruption and decay'. The EIC servants whom he met were 'extravagant, arrogant and often capricious', and they were deeply suspicious of his mission.[43] Hove received no financial support, and eventually raised a loan from a Parsi merchant. His detailed reports and diaries were no bare-boned botanical compendium. They recount the trials and tribulations of the industrial traveller. Forced to take a palankeen, retainers, and seventeen horsemen, this was not his preferred method of collecting information, nor indeed was it what Joseph Banks had imagined. But it was little different from the practice of other European surveyors and collectors of botanical and natural history specimens at the time. Schaffer's account of the surveyor Reuben Burrow's travels along the Ganges and Brahmaputra provides a similar example: 'Never solitary, always accompanied by troops of sepoys, expert pundits and other Company officers, he travelled by boat and

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41 Neil Chambers, ed., *The Indian and Pacific correspondence of Sir Joseph Banks, 1768–1820*, vol. 2, *Letters 1783–1782*, London: Pickering & Chatto, 2009, p. 290. These are drawn from the correspondence of Banks to Hove held in the British Museum, 7 January 1787, B.M. (N.H.) D.T.C., vol. 5, fols. 124–7. A revised and edited version of Hove's journal was published as *Tours for scientific and economic research made in Guzerat, Kattiawar, and the Conkuns in 1787–88 by Dr. Hove*, Bombay: Selections from Records of the Bombay Government, no. 16, 1855. Passages used here, where possible, are from 'Extracts from Dr. Hove's Journal', BL, IOR, Home Miscellaneous 374, pp. 591–665.

42 Chambers, *Indian and Pacific correspondence*, vol. 2, letter 104.

43 Mackay, 'Agents of empire', p. 38.

camel across much of northern India and along the troublesome coast south into Arakan.'[44] Hove's initial efforts to do without his palankeen blocked his access to particular areas, and without a group of armed horsemen he was very soon set upon by robbers. Indeed, he wrote early on to Banks 'November the 25th being a second time robbed of all my furniture…'. He moved on, and freed himself 'of a suspicion, under which I laboured daily, not only of the Inhabitants, but also of the Europeans'.[45]

Hove narrated the hostility of the people in some of the districts through which he passed. Seeking the raja's permission to visit Tanapoor, where the finest cotton was produced, and indeed presenting him with a fine shawl, he met with frustration: 'this was what I ardently wished, for as the people behave rather unruly on our first passing here I hoped that the Rajah's association with me would have a check on them for any future insults' – but it rained and the raja would not go further than the village.[46]

Hove conducted a detailed survey of the fine cotton and indigo plantations in the Broach cotton district, but encountered secretive behaviour when attempting to gather specimens and seeds. In Serapoor, where the finest cotton grew, he went to the overseer with a reward asking for a little for medical purposes: 'accordingly after binding me to secrecy of not telling it, which was what I wished, he gave me the quantity that is marked under No. 8 and promised me some seeds as soon as the cotton is cleared off'.[47] He also detailed the different types of cloth produced in Broach, where 'every street swarms with different castes – Arabs, Moguls, and the many tribes of Gentoos'.

Hove then went on to investigate spinning and weaving in Serapoor:

> Today I sent my interpreter to enquire and find out the places at what part of the town the weavers and carders resided who gave me on his return a very unsatisfactory report – that this branch is chiefly performed by women, who cannot be seen by any other person but their own caste. I therefore desired him to bring me a machine, but in this I was likewise disappointed, and the cause has been ascribed to me for the superstition with which the women are prepossessed, that they could never spin so well if their work came to the light of a stranger. However they did not scruple selling it, of which I could have purchased in any quantity, but to part with their implements, they would not on any account.[48]

Hove conveyed great admiration for the skills he witnessed. He investigated the division of labour in the crafts, and commended the practices and customs to English manufacture (Figure 1):

> This country method of weaving would do very well in England, the country so much more favourable on account of its moderate climate which in this country the weavers are obliged to moderate, by artifice however; only in large manufactories where everyone could mind his own Branch, which in the time of a year would become to

44 Schaffer, 'Asiatic enlightenments', pp. 93–4.

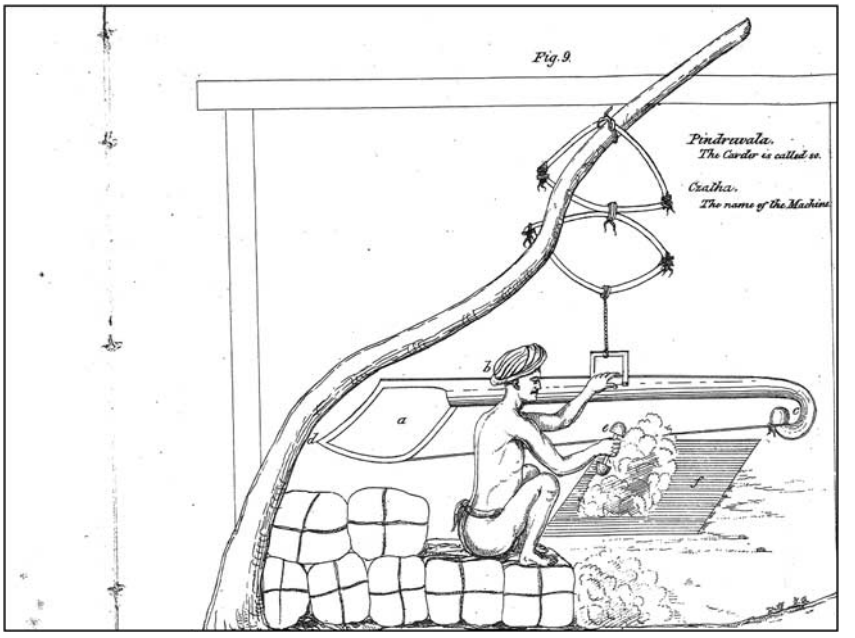
45 Chambers, *Indian and Pacific correspondence*, vol. 2, Letter 209, Hove to Banks, Bombay, 2 February 1788, p. 293.

46 BL, IOR, 'Extracts from Dr. Hove's Journal', p. 622.

47 *Ibid*., pp. 641–2.

48 *Ibid*., pp. 642–4.

Figure 1. A Surat carder at work. Source: Anton Hove, *Tours for scientific and economic research made in Guzerat, Kattiawar, and the Conkuns in 1787–88 by Dr. Hove*, Bombay: Selections from Records of the Bombay Government, no. 16, 1855, fig. 9.



> him fine spinning and weaving as familiar as the coarse cloth is to him at present … the weavers live here separately from the rest of the mechanics, and none of them ever interfere with his neighbour's branch solely minding his own, and so quits it to his posterity. I am confident if the weavers in England would be persuaded of imitating this country agreement they would soon be convinced and find their mutual interest of containing in the separate branches.[49]

He noticed careful quality control, as rooms in artisan dwelling where looms were located were cut off from natural light. Lighting by lamps made it easier to detect faults in the yarn.[50]

The organization of production was typical of weaving towns and villages in western India, where most of the producers belonged to specialized artisan castes and manufactured goods for distant consumers. They were not like the part-time rural weavers of European proto-industrialization, nor like rural manufacturers in other parts of India. Their textiles were also created in several stages of production, in which distinct workshops, castes, and households specialized. There is evidence of a mixed system during the eighteenth century, of family units and larger workshops supervised by merchants.[51]

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49 *Ibid*., p. 665.

50 Hove, *Tours*, pp. 140–1. This point was noted by Douglas Haynes, *Small town capitalism in western India: artisans, merchants, and the making of the informal economy, 1870–1960*, Cambridge: Cambridge University Press, 2012, p. 134.

51 Haynes, *Small town capitalism*, pp. 31–3.

Hove described Surat during this period of the later 1780s as place of vibrant and growing trade: 'it not only pays and defrays its own great expense, but likewise furnishes Bombay with three to four lacs of rupees per year'. He found a new shipbuilding industry there, building ships from teak for use in private trade. The exports included fine cotton, indigo, Ahmedabad carpets, silks, kincobs,[52] ilachu (satin), and cotton cloth; imports were of coffee, sugar, spices, iron, copper, and ivory.[53] His survey of the region conveyed a picture of a thriving industrial and mercantile economy, and one that was not, even at this late stage, under the unchallenged control of the Company. Indeed his account concurs with recent historical research by Subramaniam, Nadri, and Haynes. They describe the growth of Surat during the eighteenth century, and the new concentration of weaving in the town. The weavers were, moreover, operating in highly competitive markets, with access to Portuguese, Armenian, and Indian merchants, thereby frustrating any tight economic control by the EIC.[54]

Hove's precise account of cotton cultivation and processing was duly delivered to Joseph Banks, but Hove was in disfavour. It was said that no copy of it was ever lodged in the India Office, though much of it can be found as 'Extracts from Dr. Hove's Journal' in the India Office Records under 'Home Miscellaneous'.[55] An edited version of the journal was not published until 1855.[56] The EIC in Bombay thwarted Hove's efforts to return home, which he only achieved by buying passage for himself and his collection on a Danish ship.[57] He received no thanks from Banks, who advised Lord Hawkesbury, the first President of the newly created Board of Trade, to order Hove home, after he became aware of the expense of his travel.[58] The loans that Hove relied on from Parsi merchants carried an exorbitant interest rate, and his bills were drawn on Lord Hawkesbury. The armed guard with whom he had first travelled grew to forty-eight. Hawkesbury asked Banks to summon Hove home in September 1788, but demanded that the Directors of the Company advance him the funds to secure a passage.[59] Banks ordered Hove home in a peremptory letter sent on 30 September 1788:

> I was surprised & very disagreeably so by the Contents of your Last Letter … the Expence you have incurrd is /very/most/unjustifiably Enormous …. Had Government thought the Object you was sent to obtain of sufficient value to have been purchased

52 Also known as 'kinkobs' or 'kinkhabs', these were pieces of woven silk and gold cloth, produced in India from as early as 1500 BC (see Brenda M. King, *Silk and empire*, Manchester: Manchester University Press, 2005, p. 66).

53 Hove, *Tours*, pp. 176–8.

54 Nadri, *Eighteenth-century Gujarat*, p. 26; Lakshmi Subramanian, 'Power and weave: weavers, merchants and rulers in eighteenth-century Surat', in Ashin das Gupta, Rudrangshu Mukherjee, and Lakshmi Subramanian, eds., *Politics and trade in the Indian Ocean world: essays in honour of Ashin Das Gupta*, Delhi: Oxford University Press, 1998, pp. 52–82; Subramanian, 'Political economy', esp. pp. 268–75; Haynes, *Small town capitalism*, pp. 33–6.

55 BL, IOR, H. India Office Home Miscellaneous Series *c.*1600–1900.

56 See note 41.

57 Hove, *Tour*, p. 196.

58 John Cannon, 'Jenkinson, Charles, first earl of Liverpool (1729–1808)', *Oxford dictionary of national biography*, Oxford: Oxford University Press, 2004, online edn 2008, http://www.oxforddnb.com/view/article/14737?docPos=1 (consulted 3 December 2012).

59 Chambers, *Indian and Pacific correspondence*, vol. 2, Letter 240, Jenkinson to Banks.

> at the Expense of Presents to Chiefs & the Hire [of] Guard's you would have been Enabled to have done /so/ … you have now nothing to do … but instantly on the receipt of this to repair to Bombay bringing with you such things as you have been able to procure & Ship yourself & them on the very first Ship which returns to Europe … the Governor of Bombay is ordered to furnish you with money sufficient to bring you home …[60]

Knowledge exchange also came from Christian missions, where physicians and natural historians were established. Jesuits and other Catholics in the French factories, and Lutheran Pietists and Moravians at the Danish colony of Tranquebar (Tharangampadi) on the Coromandel coast, engaged in an enlightened gathering of local knowledge, as did the Baptists, who settled with the Danes at Serampore in Bengal. These missionaries learned Sanskrit and Persian, as well as vernacular languages. French accounts of calico printing on the Coromandel coast are well known. Father Coeurdoux, a Jesuit priest in Pondicherry, questioned a number of calico painters, and hoped that his account would assist in perfecting the art of dyeing in Europe. Jean Ryhiner, a Basel chemist, drew on French accounts in 1766 and concluded that 'even granted all things equalled we could never adopt their methods, for we lack skilled craftsmen and could not keep the maintenance costs so low'.[61]

These mid-eighteenth-century accounts praising Indian craftsmanship were followed by European writings giving greater weight to chemistry and experiment, rather than to customary practice and 'accidental discovery'.[62] However, even Claude-Louis Berthollet, building on Ryhiner, acknowledged the great significance of skilled workforces. Workshops in Europe used natural dyestuffs, some of which derived from colonial plants acclimatized in European gardens, together with colouring matters and other materials from the colonies. Tacit knowledge in these workshops was as vital as in India. Berthollet sought to incorporate the new chemistry into the art of dyeing, but acknowledged as vital the tacit knowledge of craftspeople in manufacture.[63] Certainly those collecting knowledge of natural history in India in the later years of the eighteenth century remained intrigued by Indian craft practices, and included detailed accounts of these.[64]

One of those fascinated with Indian technologies and industries, including those of textile dyeing, was Benjamin Heyne, a German surgeon, chemist, and mineralogist from the Moravian mission in Tranquebar, who later worked for the EIC as Acting Botanist at the pepper plantation at Samulcotah. After the plantation was closed in 1800, Heyne was appointed to find a site in Mysore for a new botanical garden, and chose the former royal garden of Tipu Sultan at Bangalore. He was appointed Botanist and Naturalist at Madras in

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60 *Ibid*., Letter 249, Banks to Hove.

61 Berg, 'Pursuit of luxury', pp. 113–20; Riello, 'Asian knowledge', pp. 12–14; John Irwin and K. B. Brett, *Origins of chintz*, London: HMSO, 1970; Jean Ryhiner, *Traité sur la fabrication et le commerce des toiles peintes* [1766], not published until 1865.

62 Riello, 'Asian knowledge', pp. 26–8.

63 Augusto Nietro-Galen, 'Between craft routines and academic rules: natural dyestuffs and the "art" of dyeing in the eighteenth century', in Klein and Spary, *Materials and expertise*, pp. 321–53, esp. pp. 326, 334–7.

64 William Roxburgh, *Plants of the Coromandel coast*, London: W. Bulmer, 1795. See also Paul R. Schwartz, 'The Roxburgh account of Indian Cotton Painting, 1795', *Journal of Indian Textile History*, 4, 1959, pp. 47–56.

1802, and superintendent of a newly established natural history museum there. In 1804 he was appointed to the Company's garden at Bangalore, and in the years following was assigned to assist Francis Buchanan and Colin Mackenzie in the Mysore Survey. He was one of four European assistant surveyors, and was assigned to work on the survey's statistical enquiries as well as acting as the expedition's surgeon. Cost-cutting measures soon made his position impossible, and he refused to continue working on the survey.[65]

Heyne was one of a remarkable group of missionaries and natural historians at the Danish factory in Tranquebar, a group of great interest to historians of science and medicine.[66] The Pietist Lutheran Halle mission of the Franke Foundation of the early eighteenth century brought a number of physicians with a strong background and interest not just in medicine but also in broader natural history, especially botany. German missionaries also came to the Danish factory in a later Moravian mission. This group, originally sent from Herrnhut in German Lower Silesia, came to Tranquebar in 1760 at the behest of the Danish Asiatic Company, en route to establish a mission and trading factory on the Nicobar Islands. It soon became apparent that they could not settle on the islands, and they stayed instead two kilometres west of Tranquebar. They were regarded with suspicion, and opposed by the well-established Halle missionaries in the small town. The Moravians in turn kept themselves apart from the Lutherans. Unlike the Halle missionaries, they brought with them a number of artisans, and they established gardens with the purpose of seeking self-sufficiency. They connected quickly and easily with the local Tamil population, and also traded their collections of plant specimens with the EIC and Joseph Banks in London.[67]

A number of surgeons became well known in the wider world of botanical and natural history collecting. These included Johann Koenig, who had arrived in 1768 and who initiated those already there in Linnaean methodology, including Christoph John, another avid natural historian and the leader of the mission during the later eighteenth century. There were close networks among the physicians and natural historians of the Moravian mission and those centred around the EIC botanical gardens. John kept up a close correspondence with William Roxburgh and James Anderson. He traded books and seeds for the delightful

65 Desmond, *European discovery*, p. 41; Edney, *Mapping an empire*, p. 176.

66 Michael T. Bravo, 'Mission gardens: natural history and global expansion, 1720–1820', in Londa Schiebinger and Claudia Swan, *Colonial botany: science, commerce, and politics in the early modern world*, Philadelphia, PA: University of Pennsylvania Press, 2005, pp. 49–65; Sujit Sivasundaram, '"A Christian Benares": orientalism, science and the Serampore mission of Bengal', *Indian Economic and Social History Review*, 44, 2, 2007, pp. 111–45; David Arnold, 'Plant capitalism and company science: the Indian career of Nathaniel Wallich', *Modern Asian Studies*, 42, 5, 2008, pp. 899–928. For Tranquebar research, see Niklas Jensen, 'Making it in Tranquebar: science, medicine and the circulation of knowledge in the Danish-Halle Mission, *c.* 1732–44', unpublished paper presented to the European University Institute workshop 'Mission, Science and Medicine in Colonial South Asia: Situating the Tranquebar Mission(s) in the Field', 18 March 2011; Pratik Chakrabarti, *Materials and medicine: trade, conquest and therapeutics in the eighteenth century*, Manchester: Manchester University Press, 2010, ch. 4; Hanco Jürgens, 'German Indology *avant la lettre*: the experiences of the Halle missionaries in southern India, 1750–1810', in D. T. McGetchin, P. K. J. Park, and D. Sar Desai, eds., *Sanskrit and 'Orientalism': Indology and comparative linguistics in Germany, 1750–1958*, Delhi: Manohar, 2004, pp. 41–81; Esher Fihl and A. R. Venkatachalapathy, eds., *Indo-Danish cultural encounters in Tranquebar: past and present*, *Review of Development & Change*, special issue, 14, 1–2, 2009; Martin Krieger, 'Material culture, knowledge, and European society in colonial India around 1800: Danish Tranquebar', in Michael North ed., *Artistic and cultural exchanges between Europe and Asia, 1400–1900*, Farnham: Ashgate, 2010, pp. 53–72.

67 See Chakrabarti, *Materials*, pp. 178–80.

printed calicoes he and his wife craved: 'Mrs. John and I are most anxiously waiting for the kindly promised long cloth & chintz & if we don't get them soon, we must return to the primitive state of Adam & Eve.'[68] Meanwhile, the herbaria sent to Halle by the Pietists of Tranquebar were followed by Roxburgh's great botanical publication.[69]

The celebrated Coromandel trade in textiles to Europe complemented a much older trade to many parts of Asia, and to the Persian Gulf and Arabia. Telugu and Tamil Hindu merchants jostled with Muslim, Jewish, Portuguese, and Armenian merchants, and many other European private traders. English private traders used the Danish flag as a cover, and the Danes in 1776–77 were the principal carriers of textiles on private account, sailing directly to Copenhagen. They visited Porto Novo each year, traded private goods to Southeast Asia, and had access to the Manila trade after 1742.[70] These trading links among Europeans along the coast underpinned other close interpersonal connections, including the exchange of, and trade in, natural knowledge and specimens.

Heyne's industrial surveys in the 1780s and 1790s arose out of these religious, scientific, and commercial networks. His accounts show an intense curiosity in dyeing techniques, in the extraction processes of the fabled diamond mines of south India, in the skilled labour that produced fine Indian iron and steel, and a range of other useful industries from copper to saltpetre and soda manufacture. These accounts were sent to Christoph John at the Tranquebar mission as Heyne wrote them, then circulated to William Roxburgh in the early to mid 1790s. A number of them were revised and entered into Reports to the Board of Control, and several were further revised and finally published in 1814.[71]

One could analyse Heyne's surveys as being akin to later enterprises of colonial science, such as the Survey of India established in 1878, or the earlier topographical surveys of Francis Buchanan.[72] Or one could see him as engaging in another form of economic botany.[73] One can look for underlying orientalist assumptions in the surveys, and the political economy of empire framing their financing and their output. Above all, however, it is important to look at the texts, and the efforts to describe, codify, and analyse the industrial processes of India.

Like a number of natural historians before him, Heyne investigated textile dyeing, drawing on both observation and his chemical knowledge. He wrote a report on the processes during his travels in the later 1780s, which was eventually published as Tract XI, 'Mode of dyeing red cotton yarn, practised on the Coast of Coromandel', in 1814.

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68 BL, IOR, Roxburgh MSS, Eur D809, letter from John to Roxburgh, 29 September 1789.

69 William Roxburgh, *Plants of the coast of Coromandel, presented to the Hon. Court of Directors of the East India Company*, London: W. Bulmer & Co, 1795. See Desmond, *European discovery*, pp. 39–80.

70 Bhaswati Bhattacharya, 'Ports of Coromandel and trade in the Bay of Bengal in the eighteenth century', in Prakash, *History of Science*, pp. 326–7.

71 Heyne's formal reports were held in BL, IOR, F. Board of Control Records 1784–1858. See also Benjamin Heyne, *Tracts, historical and statistical, on India: with journals of several tours through various parts of the peninsula: also an account of Sumatra in a series of letters*, London: Robert Baldwin, 1814.

72 Francis Buchanan, *A journey from Madras through the countries of Mysore, Canara and Malabar*, London: W. Bulmer & Co., 1807.

73 Marika Vicziany, 'Imperialism, botany and statistics in early nineteenth-century India: the surveys of Francis Buchanan (1762–1829)', *Modern Asian Studies*, 20, 4, 1986, pp. 625–60; Arnold, 'Plant capitalism'; Gascoigne, *Joseph Banks*, pp. 201–8.

He commented that at the time he had written the piece he was not aware of what was known of the processes in Europe. He had found, though, by the time he came to the book, that there were accounts by Chaptal and Berthollet that demonstrated close similarities between dyeing methods in the Levant and India. He nevertheless considered the priority of his account and its value from 'actual inspection of the processes':

> Though the methods of Indian dyers are exceedingly tedious and complicated, and though they are utterly unable to explain the rationale of their processes, yet the beauty of their colours cannot fail to be admired, and must inspire us with the opinion that a knowledge of their methods might improve the processes of the European dyers … while the application of the light of chemistry to explain the nature of the Indian processes, to enable the enlightened artist to throw out all the useless steps, might contribute more to the improvement of this beautiful art than even the most sanguine is at present aware of.[74]

He explored large areas to the north of Madras, especially the Northern Circars, and into the interior as well as coastal areas, through present-day Andhra Pradesh and Orissa.

Heyne's longer experience of living in India, and his linguistic capacities, did not make his travels easier or less expensive than those of Anton Hove. He described journeys where

> my suite consisted of near forty persons: twelve palankeen boys for myself, a flambeau [bearer]; carriers for baggage, books and provisions, servants, a draughtsman and two plant collectors and a small guard of armed men is … necessary as a protection from robbers and tigers … People in England have no conception of the labour and expense which it costs to obtain a box of insects or plants …[75]

His account was also absolutely clear on the important role of his local assistants. Unlike those nineteenth-century naturalists Reinwardt and Humboldt, presenting themselves as heroic figures directly encountering nature, Heyne acknowledged his skilled plant collectors:

> In this country a man who is botanically inclined cannot do without people to collect plants. For botanizing in person for any length of time is quite out of the question. I have some collectors who have made such progress in the Linnaean system as to be able to distinguish male flowers from female in the Dioecious class, in plants which they have never seen before.[76]

Like Hove, Heyne encountered hostility and efforts to block his investigations in the copper mines, at areas of soda and saltpetre production, and in the diamond mines; he admired 'the extraordinary skill of the People in the discovery of Diamond mines … the knowledge of which, they have always been very tenacious in keeping to themselves as much as possible'.[77] At times, this secrecy arose from the power of the local zamindars and fears and hostility related to Europeans. In the relatively wealthy country of Zamindar Nasareddy,

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74 Heyne, *Tracts*, p. 204.

75 *Ibid*., p. 248.

76 *Ibid*.; Weber, 'Encountering', pp. 41–2. See also Edney, *Mapping an empire*, pp. 79–83, discussing the role of Indian informants on Buchanan's Mysore Survey.

77 BL, IOR, Board of Control F/4/1, p. 135.

he found the 'bazaar is large and well provided tho' such is the jealously of powers that a stranger cannot get anything without the zamindar's particular leave even not a pan of rice or a pot which I affirm from melancholy experience having been starved there a whole day in the midst of plenty'.[78] He found superior copper in the mines of Callastry, Venkatygherry, and Nellore 'but everyone … seemed anxious to keep us ignorant of these mines'. There were similar accounts about limestone deposits: 'This strange conduct originated in both places from the same cause: the mandate of the Rajah to conceal everything, as far as possible, from the prying eyes of an European.'[79]

In other cases, secrecy was connected with local skills, cults, and deities. At the diamond mines near Cuddapah, which had been worked for several hundred years, Heyne reported that a group of labourers working a new mine 'were offended at my coming on horseback near the mines … saying that Ammawāru (the sanguinary goddess of riches) would not allow such liberties to be taken, at a place under her particular influence … [They] were soon pacified on being assured that I had come among them by leave of her ladyship.'[80] His Reports on the Diamond Mines sent to the Board of Control in 1796 admired the secret knowledge of finding the diamond deposits:

> it may appear strange that the inhabitants of the hills, alone should possess the knowledge of so curious and important circumstance … I am inclined to think that the extraordinary skill of the People in the discovery of Diamond mines might almost afford a persuasion, that their mountainous retreats, abound with minerals and precious stones, the knowledge of which, they have always been very tenacious in keeping to themselves as much as possible.[81]

Heyne visited diamond mines and iron works, textile centres and areas manufacturing saltpetre and soda. He also provided detailed maps of the location of resources and minerals throughout the areas in which he travelled (see Figure 2).[82] The fabled diamond mines of Golconda had long declined by 1790, as the focus of Europe's trade in diamonds had shifted to producers in Brazil.[83] However, the mines in surrounding areas continued on a smaller scale. Heyne explored those of Mallavilly, south-west of Ellore, in present-day Andhra Pradesh. He provided detailed accounts of the diamond beds, how they were worked, and the division of labour.

> Sixteen persons, men and women, are employed in each mine, and each received one pagoda of wages per month. Half of them are employed in mining and the other half in carrying on the subsequent operations. These people are inhabitants of the neighbouring villages, suders, who from their infancy, are brought up to this work, and with

78 BL, IOR, Roxburgh MSS, Eur D809.

79 Heyne, *Tracts*, pp. 111–12.

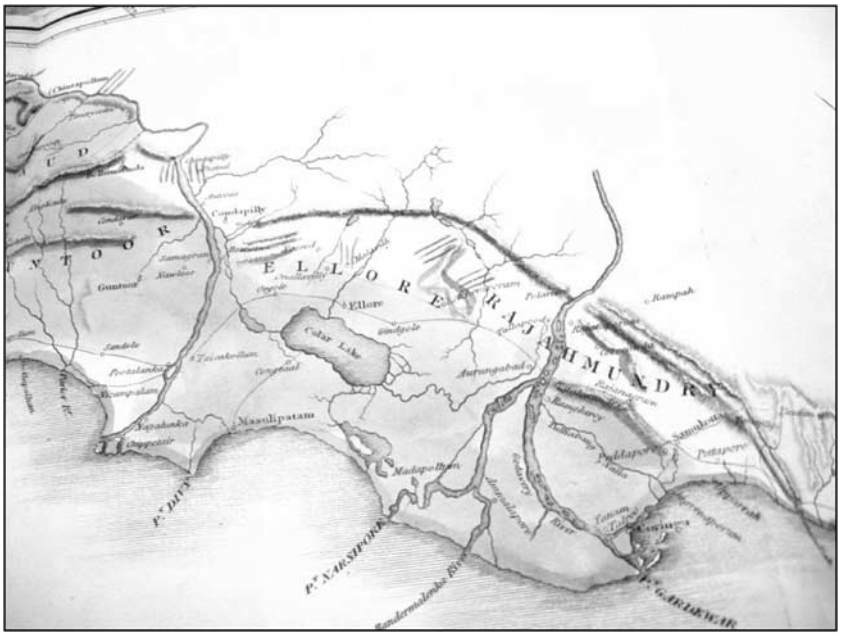
80 *Ibid*., p. 95.

81 BL, IOR, Board of Control F/4/1, p. 135.

82 Heyne, *Tracts*, 'Map of the Circars', facing p. 282.

83 Søren Mentz, 'English private trade on the Coromandel Coast, 1660–1690: diamonds and country trade', *Indian Economic and Social History Review*, 33, 2, 1996, p. 165; Dario Gaggio, 'Diamond industry', in Joel Mokyr, ed., *The Oxford encyclopaedia of economic history*, Oxford: Oxford University Press, 2003, vol. 2, pp. 76–82.

Figure 2. 'Map of the resources and manufactures of Ellore'. Source: Benjamin Heyne, *Tracts, Historical and Statistical, on India*, London: Robert Baldwin, 1814.



> the ideas necessary for the undertaking, they pride themselves on their honesty to their employers.[84]

His earlier account found people from the age of twelve working in the mines. The men 'dig the ground … the women and children carry in baskets on their heads the several strata of earth to the places allotted for each sort'. The men removed the stones with gravel and earth, and women and boys cleared them from the earth. Then men picked through the gravel for larger, then smaller stones in a series of stages. Knowledge was based in long practice.[85]

Heyne's present of a gold fanam to the headman made him very communicative.[86] He 'pointed out a variety of small stones that were thrown away … and assured me they always indicated the presence of diamonds when they occur in beds at some depth underground'.[87] At another point, Heyne gave a morose servant of the raja two yards of scarlet broadcloth and he lightened up a bit. He 'told me it was his business to search in the river Hebe after the rains for red earth washed down from the mountains in which earth diamonds were always found'.[88]

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84 Heyne, *Tracts*, p. 101.

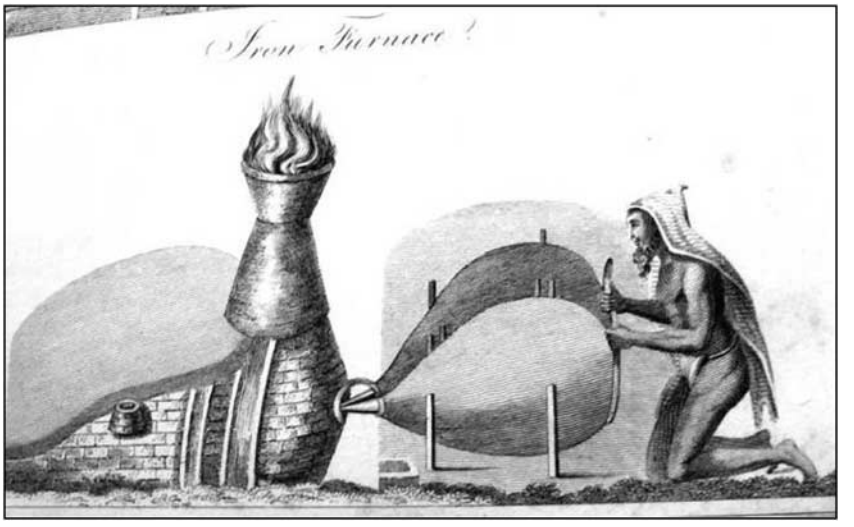
85 BL, IOR, Roxburgh MSS, Eur D809, 'Report of an excursion to the diamond mines at Mallavilly and iron works at Ramanakapellah near Ellore', p. 11.

86 A fanam was a gold or silver coin, the latter worth 1/8 of a rupee. See http://www.merriam-webster.com/dictionary/fanam (consulted 3 December 2012).

87 Heyne, *Tracts*, p. 97.

88 IOR, BL, Roxburgh MSS, Eur D809, p. 11.

Figure 3. An iron furnace at Yeragutty. Source: Heyne, *Tracts*, facing p. 190.



Heyne wrote of labour forces that 'are not guarded, and do not seem to be under any control. Everything is left implicitly to their good faith; which at all times is, perhaps the best way to ensure fidelity.'[89] He thought that the diamonds were still well worth pursuing: 'the country is by no means exhausted, and that abundance of diamonds might be procured should an increased demand for them arise'. Those diamonds excavated and cleaned were bought by merchants who traded them in Madras. 'The larger crystals would, I conceive, answer the European market, and might be cut into brilliants.'[90]

Heyne went on to another of India's recognized industries, its iron manufacture. After an earlier report on the iron works at Lechemporam, he wrote 'my attention to this branch of science or rather Indian Manufactures has been raised as that I could not but avail myself of the first opportunity that was offered to see works of the kind at other places'. He had a 'hope of becoming useful by rendering myself enabled to point out a place, where iron works of consequence might be erected with a full prospect of success'.[91]

He watched iron being smelted at Yeragutty, near to Satghur, where three workmen from three separate families smelted iron three times a day making 360 pieces, selling at 40 rupees: 'This is all that they get for their labour and skill, and all that they have for the support of three families during the course of a year.' He set out the process, and included a drawing (see Figure 3).[92] Heyne found the iron smelters of the Northern Circars equally poor. A group of eight or nine miners, smelters, wood cutters, and labourers could produce 'considerable iron … the finest in every respect for tools, razors etc … the demand for

89 Heyne, *Tracts,* p. 96.

90 *Ibid*., pp. 101, 107.

91 IOR, BL, Roxburgh MSS, Eur D809, p. 24.

92 Heyne, *Tracts*, p. 190.

it is great'.[93] However, notwithstanding their diminutive scale, these smelting works attracted 'the attention of every curious observer, on account of the simplicity of every part of the process and the goodness of the iron obtained'.[94]

Heyne's observations were among the earliest accounts of artisanal iron smelting. Tirthankar Roy draws on other early and mid-nineteenth-century accounts of semi-nomadic groups of iron smelters and peasant smelters who worked with the disadvantage of the small scale of their production, low labour productivity, and the high cost of their charcoal fuel in comparison with the rapidly innovating and much larger-scale British iron industry.[95]

Where possible, Heyne attempted to connect his formal scientific knowledge to the processes he witnessed. At the diamond mines of Mallavilly he discussed Bergman's dissertation on the earth of gems, and debates over Boyle's theories on gems: 'This is a subject on which I have made some experiments, read much and thought not a little. I may hereafter find time to collect my inferences.'[96] Heyne concluded that diamond mining and processing there, though much reduced from its former times, was still viable. He assayed the ores in the copper mines of Ayricondalah, heating these in a crucible with a flux, but found the experimentation process in the field inconclusive.[97] While admiring the quality of iron produced by artisan smelters, Heyne regretted the lack of coal, and hence the lack of cast iron then leading the British iron industry.

Indian steel (*wootz*), soon to be much investigated by the Royal Society, was another matter. Heyne thought that there was much to be gained in promoting its manufacture, for English steel

> is worse in quality than it was some thirty or forty years ago … If the steel makers of India were made acquainted with a more perfect method of fusing the metal, and taught to form it into bars by tilt hammers, it might then be delivered here at a price not much exceeding that of cast steel. I am of opinion it would prove a source of considerable Revenue to the country …[98]

Wootz was already the subject of great admiration and experimentation at the time of Heyne's travels. George Pearson's paper to the Royal Society in 1795 reported on specimens sent by Dr Helenus Scott of Bombay, and on experiments by Stodart, and the prevailing view that '*wootz* is superior for many purposes to any steel used in this country'.[99]

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93 *Ibid*., p. 218.

94 *Ibid*., p. 219.

95 Roy, 'Knowledge', pp. 381–2; Tirthankar Roy, 'Did globalisation aid industrial development in colonial India? A study of knowledge transfer in the iron industry', *Indian Economic and Social History Review*, 46, 4, 2009, pp. 585–7.

96 Benjamin Heyne, 'Cursory observations made on a tour from the banks of the Kistna to Timmericatah', IOR, BL, Eur D809, p. 18.

97 *Ibid*.

98 Heyne, *Tracts*, p. 364.

99 George Pearson, *Experiments and observations to investigate the nature of a kind of steel, manufactured at Bombay and there called wootz*, read before the Royal Society, 11 June 1795, p. 5. See also David Mushet, 'Experiments on wootz', *Philosophical Transactions of the Royal Society of London*, 95, 1805, pp. 163–75; J. Stodart and M. Faraday, 'On the alloys of steel', *Philosophical Transactions of the Royal Society of London*, 112, 1822, pp. 253–70.

However, artisanal smelting declined with the entry of British and Swedish iron into India in the nineteenth century. Pasartharathi notes European recognition of the quality of Indian iron and steel, but recounts the failure of attempts to establish larger-scale iron works on European models. The most notable case was the Porto Novo iron works, backed by the EIC and granted an exclusive privilege by the Madras Council in 1825. After some early success selling iron to the Woolwich Arsenal, it limped along, never profitable, and eventually closed in 1860.[100]

Heyne's industrial surveys were made in the 1780s and 1790s, some probably during the period when he was at the Tranquebar mission, and others later, while he was Acting Botanist at Samulcotah. He set an agenda coinciding with that search for 'useful knowledge' connecting with Mokyr's 'industrial enlightenment'. Heyne admired resources, skills, and above all good-quality products. He attempted to codify industrial processes, and mapped mineral deposits and mines on his journeys.

Conclusion

The tours and reports on Indian industry of two European naturalists and savants reveal the interlinking of Asia's and Europe's manufacturing economies, where the demands for Asian imports fed into those of Europe's industrialization. Mokyr's concept of an 'industrial enlightenment' explores connections between a European world of 'savants', inventors, and manufacturers, seeking routes to economic improvement, and the commercial and economic culture of industrialization. One result of this was European travel and investigation of industry in Europe's system of competing states. We know a great deal about the travels of manufacturers and artisans across Europe's borders during the early industrial period, and those of European savants collecting knowledge of Europe's arts and manufactures, but that enlightened investigation of industry extended beyond Europe. Europeans also interrogated Asian resources, industry, and craft, and relied on the 'tacit' knowledge of miners and craftsmen whom they encountered.

The travels of a Polish naturalist and a German Moravian were entangled with the colonial and commercial aims of the British state and the English East India Company, as information was gathered on India's products and processes. While Anton Hove was seeking out Gujarat's finest raw cotton, Benjamin Heyne was testing the quality of South Indian iron and calculating the profitability of trade in Indian saltpetre. Thus two eighteenth-century naturalists pursued the questions and methods of other travelling investigators in Europe to produce detailed accounts, illustrations, and maps of Indian industry well before the colonial surveys and cartographic enterprises of the early to mid nineteenth century. Their efforts to codify India's resources and manufactures fell foul of the priorities of EIC factors and governors. Their lucid and informed accounts of the high-quality manufactures and significant resources of two regions of India were therefore relegated to the archives of the India Office Records, and did not see the light of day in publication until the early and mid nineteenth century.

Though we cannot claim for these accounts any impact on European practices, we witness in the texts a wide intellectual endeavour extending from Europe to distant parts of

100 Roy, 'Knowledge', pp. 379–85; Roy, 'Did globalisation', pp. 593–4; Parthasarathi, *Why Europe*, pp. 234–9.

India. Correspondence networks with other European investigators and natural historians in India and Europe connected Hove and Heyne to the wider public culture of the 'industrial enlightenment'. These contributed to the questions, theories, and methods that informed their travels and writing. The detail of their accounts also provides us with insight into eighteenth-century investigations of 'tacit' knowledge in a distant part of the world, and attempts to 'codify' these. Yet, as we see from these cases, what European savants travelling in the colonial setting of eighteenth-century India could achieve was strictly limited by the English East India Company and the British state.

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